Planning And Design Of Irrigation System For A Farm In Tanjavur By Using Remote Sensing

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Abstract

A methodology was developed using a Remote Sensing to select, design, install and manage an irrigation system for a farm. Remote Sensing was used to develop different thematic layers, each consisting of a particular attribute required for analysis of alternative irrigation system types. These layers included data such as: topography, soil texture, soil water retention, bulk density, infiltration rate of water and field drainage system. These layers were used with water availability and water demand to design and plan the farm irrigation systems. A case study for blueberry orchards with drip irrigation was developed. The Remote Sensing facilitated irrigation planning, although additionally AUTOCAD was used to design the irrigation method. Remote Sensing was found to be a useful tool for a general farm planning analysis. Our study area is Tanjavur which plays vital role in water source for agriculture. Irrigation system in Tanjavur is very essential to develop to accumulate the water sources.

Keywords: Planning, Design, Irrigation System, Farm, Tanjavur, Remote Sensing

1.INTRODUCTION

In the near future, irrigated agriculture will need to produce two-thirds of the increase in food products required by a large population increase (English et al., 2002). The growing dependence on irrigated agriculture coincides with an accelerated competition for water and increased awareness of unintended negative consequences of poor design and management. Irrigation systems are selected, designed and operated to supply the individual irrigation requirements of each crop field on the farm while controlling deep percolation, runoff, evaporation and operational losses to establish a sustainable production process. Considering the stupendous task and constraint of time in developing the ultimate irrigation potential, it is necessary to use the modern methods of surveying and analysis tools. Remote Sensing and Geographic Information System (Remote Sensing) with their capability of data collection and analysis are now viewed as efficient and effective tools for irrigation water management. The capability of Remote Sensing to analyze the information across space and time would help in managing such dynamic systems as irrigation systems.

Soil survey data and Remote Sensing are important tools in land use planning. Intertwined, they represent an invaluable and underutilized resource. Hazrat et al. (2003) found that the Remote Sensing is an important tool that can be used for optimal allocation of water resources of an irrigation project. Mean water balance components results for different months were stored in Remote Sensing databases, analyzed and displayed as the monthly crop water requirements maps.

Chowdary et al. (2008) showed that satellite Remote Sensing coupled with Remote Sensing offers an excellent alternative to conventional mapping techniques in monitoring and mapping of surface and sub-surface waterlogged areas. El Nahry et al. (2011) found that for center pivot irrigation under precision farming, Remote Sensing and Remote Sensing techniques have played a vital role in the variable rate of water applications that were defined due to management zone requirements. Fertilizers were added at variable rates. Crop water requirements were determined in variable rate according to the actual plant requirements using SEBAL model with the aid of FAO CROPWAT model. Hatzios & Kriton (2000) used the soils information recompiled from an uncorrected aerial photographic base to a USGS topographic base map. Soils data were added to numerous other data layers and images. Interpretation maps flooding frequency maps, and runoff maps were created from map unit interpretive records. Utset & Borroto (2001) used the Remote Sensing to create raster layers with soil electrical conductivity and topographical altitudes to determine the border of saline effect zones. Szalai et al. (2004) analysed several applications of the Remote Sensing in climatology, meteorology and regional evapotranspiration, as well as, to determine irrigation requirements. Xiaopveng et al. (2011) developed an irrigation scheduling method by integrating the ‘checkbook irrigation method’ into a Remote Sensing -coupled soil water and nitrogen management model. The soil water and crop information required by the checkbook method and previously collected from field observations, was estimated by the soil water and nitrogen management model.

Irrigation is one of the most important inputs for an efficient and sustainable agricultural production (Gundogdu et al., 2002).The irrigation water management has key role in increasing food grain production with less water as well as to meet the ever increasing demand of other water uses. Management of irrigation system reduces water demand, saving water for other uses and further helps in improving agriculture productivity. Irrigation management is one of the major challenges for the irrigation professionals and managers because it involves multi tasks, multi stakeholders with varying goals. An efficient water management allows optimization of available water, an effective control on the quality of agricultural products and further helps in reduction of the adverse environmental impacts of irrigation.

With the rapid advances in computer technology, water agencies and researchers around the world are investing extensive effort to develop generalized computer models/tools for simulating irrigation management. Although, the development of software for improved management of irrigation systems has been moving very slowly as compared to other sectors, in past a number of simulation models, irrigation scheduling models and decision supporting system to support irrigation management were developed (Fortes et al., 2005; Todorovic and Steduto, 2003; Heinemann et al., 2002). Computer based systems and tools help the decision maker to manage irrigation system quickly and efficiently. Few computer-based tools/system have become popular among the irrigation experts and authority. These tools are effectively applied in the past for irrigation management. This paper encompasses review of irrigation management tool/systems developed in the past to answer irrigation water management questioning. This paper includes the importance of Remote Sensing and its integration with the irrigation management tools/system for improved irrigation management. Further, a brief review on customization of Remote Sensing along with needs and potential of development of Remote Sensing based tool for better irrigation management is discussed.

Geographic Information Systems has been used to improve the irrigation water management (Calera et al., 1999; Todorovic & Steduto, 2003; Satti & Jacobs, 2004; and Singh et al., 2006) and for irrigation scheduling have built a database program for enhancing irrigation district management to manage detailed information about district water management and to promote better on-farm irrigation practices.

Remote Sensing has the capability to manage many layers, integrate and analyze spatial data from different sources, with diverse formats, structures, projections and helps in spatial modeling (Goodchild, 1992). Remote Sensing is capable to import the most common data formats both for raster and vector maps. The basic functions of Remote Sensing are data collection and capturing; data storing, processing and analysis; store, quarry and analyze data; production of data; display data; produce output from the information in it. Remote Sensing is a collectively broad term that contains a number of technologies, processes, and methods. It is attached to many operations and has wider applications related to engineering, planning, management, transport/loRemote Sensingtics, insurance, telecommunications, and business.

1.1 The Application Of Remote Sensing

Has become popular in water resources management due to its dynamic process to incorporate data and display results. REMOTE SENSING techniques are more time and cost efficient than the conventional field techniques and can be used to formulate a management plan much more efficiently and link land cover data to topographic data and to other information concerning processes and properties related to geographic location.

Information about a farm is needed to plan and implement an optimized farm practice that leads to effective and efficient water use. This information must be based on detailed spatial and temporal data. Amongst the most relevant are soil properties, topography, crops, water supply and weather (historical and real-time).

Good planning is essential for successful irrigation, including: 1) The selection of an irrigation system that provides the best practical and economical irrigation system alternative, 2) the design and installation of a system according to standards and accepted engineering practice and 3) system management that ensures a correct and timely application of water that is based on crop requirements and avoids unnecessary water use (Holzapfel et al., 1985a).

Furthermore, to increase production efficiency and to diminish environmental impacts, agricultural problem-solving should incorporate technologies that can improve the quality and timeliness of data.

1.2 Remote Sensing

The Remote Sensing has not been used in selection, design and management of surface and pressurized irrigation systems. For these reasons, the objective of the present study was to develop a Remote Sensing -supported irrigation design and planning methodologies at the farm level and to apply it in a case study.

The specific objectives were to: 1) evaluate Remote Sensing as a tool for farm-level irrigation system design and planning, 2) analyze the spatial variability of the parameters that affect design and management of irrigation systems, 3) develop a procedure for optimal design of irrigation systems taking into account spatial variability, and 4) develop a support for a water distribution system planning.

In the past, most of the studies consider the watershed management that consists of water resources planning for entire river basin/catchment/sub-catchment scale. The challenge on watershed management at macro/micro level is to make reliable assessment of water demand and availability with the given data. The major gap in the evolving watershed management concept at macro or micro level is due to very limited distribution and exchange of information and datasets caused by different norms, policies, institutional and organizational factors. Hence, it was found that, for studying the detailed aspects of soil and water management as well as to implement hydrological modeling techniques with adequate datasets, it is necessary to understand watershed management at micro level for decentralized planning. Also, land irrigability and capability classification for micro level watershed planning are needed so that the farmer can use better parcels for intensive cultivation with proper conservation measures and soil improving practices.

Technologies are available to solve many watershed problems (irrigation scheduling, water release cycles in canal command area, etc.). However, methods are further needed to effectively demonstrate the benefits of instituting environmentally sound watershed management programmes. Technologies need to be demonstrated in an effective way for easy accomplishment of planes and implementations by the users. These tools and techniques also need to be cost effective. Besides, the physically based hydrological models are very complex and have lots of input parameters and, as previously explained, the major problem is being related to availability of adequate database. Hence, viable methodology must be prevailed over to serve the novice user. It was found that technologies alone are not producing the expected results to facilitate sustainable development and natural resource management. It is vital to carry out further studies, research and analysis on the concepts and approaches of watershed management. Studies are required on what has been accomplished with existing ones and how these can be made even better.

Remote Sensing is a collection of computer hardware and software, data and skilled personnel for managing and analyzing geographic data (Maguire et al., 1991). In Remote Sensing data is represented in the form of points, lines, polygons or pixels. Rather than just a map, in which colours and symbols represent geographical features, the user can interact to varying levels with a Remote Sensing. At present, Remote Sensing technology is widely applied in several fields such as natural resource management, agriculture management, commercial, urban and regional management to address complex and multidisciplinary planning and management problems at regional and global scales.

Remote Sensing has gained widespread acceptance as an important versatile tool because of its ability to carry out complex spatial operations and capability to link spatial and non spatial data Remote Sensing has the capability to manage many layers, integrate and analyze spatial data from different sources, with diverse formats, structures, projections and helps in spatial modeling (Goodchild, 1992). Remote Sensing is capable to import the most common data formats both for raster and vector maps. The basic functions of Remote Sensing are data collection and capturing; data storing, processing and analysis; store, quarry and analyze data; production of data; display data; produce output from the information in it. Remote Sensing is a collectively broad term that contains a number of technologies, processes, and methods. It is attached to many operations and has wider applications related to engineering, planning, management, transport Remote Sensingtics, insurance, telecommunications, and business.

1.3 Remote Sensing In Irrigation Management

REMOTE SENSING is a familiar and popular tool for management and decision making in water resources for agricultural and conservation purposes. A spatial approach such REMOTE SENSING is particularly appropriate for the handling the spatial data in irrigation management. Remote Sensing technology such as ARC/INFO software was efficiently and effectively used in many water resources planning and management worldwide. It can help to establish agricultural water rights, support the application for drilling permits for irrigation purposes, and track water rights information. It can also be used to evaluate the loss of water from soil drainage and unlined canals, as well as help determine the suitability, cost-effectiveness, and prioritization of canal projects in planning stages. Use of Remote Sensing especially for analysing spatial water and irrigation requirements with their large volumes of spatially and temporally distributed data is widely adopted. The REMOTE SENSING capability to integrate spatial data, integrating Remote Sensing data and handling large volume of data has been popular among the irrigation experts. The integration and use of georeferenced data in irrigation management certainly requires the use of Remote Sensing technologies. Remote Sensing offer a spatial representation of irrigation systems.

Remote Sensing has capabilities to integrate database, statistics, Remote Sensing, maps with advance graphics for visualization and analysis. Spatial database of soil, rainfall, geology, land use, transportation, topography, demography and socioeconomic can be implemented for better decisions in irrigation planning and management. With its powerful capacity for management and analysis of spatial data, Remote Sensing has becomes an important tool in irrigation management (Lin et al., 2004). Over the last decade, rapid advance in computer hardware and software, combined with the development with extensive digital database, have encouraged the application of REMOTE SENSING in irrigation management. A REMOTE SENSING technique allows modeling of water demand with different scenario for soil, crop, weather and irrigation data. A REMOTE SENSING-based decision support system for real-time estimation of water demands in delivery systems was developed by Rao et al. (2004) and applied in Sone Irrigation Project, Bihar, India. Ray and Dadhwal (2001) used Remote Sensing and REMOTE SENSING for estimation of the crop evapotranspiration of command area of Mahi Right Bank Canal (MRBC) command in Gujarat, India. Spatial estimation of regional crop evapotranspiration was described by Hashimi et al. (1995) for the study area of Poudre Basin in Colorado. A Remote Sensing application to improve irrigation planning in Yemen was illustrated by Muthanna and Amin (2003). Martin (1996) used Remote Sensing for scheduling in irrigation districts to help in decision process on irrigation scheduling with an interactive, graphic interface. Most REMOTE SENSING-applications are separated from main management systems and usually require manual data export to produce map reports.

In past, many research studies have been carried out for estimation of irrigation water requirement, mostly focused on finding water requirements for different climate, soil and crop scenario. For the irrigation scheduling and modeling as farm level, large number of tools, models and decision support systems are available. Although these tools help in improvement in irrigation management in specific aspects, large number of models raise doubt about their general validity (Lozano and Mateos, 2008). Most of these available tools are limited to computation of crop water requirements, simulate soil water balance, estimate the irrigation schedule and evaluate the existing irrigation scheduling on field level. These type of Irrigation scheduling tools and models are particularly useful at farm level to support farmers and irrigation advisory services (Ortega et al., 2005). Main focus of these models was to simulate irrigation scheduling with alternate irrigation schedule at different crop stage and to simulate with different water availability. Few tools have been integrated with REMOTE SENSING for estimation of irrigation requirement to extend the work from farm scale to region level along with better irrigation management capabilities. Some of the models are integrated with Remote Sensing which expand its analysis from farm scale to region scale, enabling water resource planning and environmental studies. Some of the tools/system developed in recent years indicating aims and features are summarized and presented.

1.4 Remote Sensing With Gis Irrigation Management

Recent advances in Remote Sensing technology offers potential improvement in various disciplines along with water resources management through important water resourcerelated information. This information is potentially useful in leRemote Sensinglation, planning, water allocation, performance assessment, impact assessment, research, and in health and environment-related fields (Bastiaanssen and Bos, 1999). REMOTE SENSING and Remote sense data have many similar attribute are concerned with the digital representation of geographic phenomena and often both employ the same spatial analytical techniques to manipulate the data. The remotely sense data in conjunction with other traditional data provides valuable information on topography, land use/cover, geological feature useful in irrigation planning and management. The space and time based earth observation in Remote Sensing provides unique opportunity in handling spatial and temporal irrigation data for better irrigation management.

Remotely sense data can be used by two ways regarding irrigation management, first accessing land cover in different cover and other is through estimation of water requirement parameters. When we deal with relatively large area/surface, Remote Sensing is more useful and there is always large area when dealing with irrigation management. Remote Sensing could be important future technology for better irrigation water management. Remote Sensing data to determine actual evapo-transpiration and crop water stress for managing irrigation systems was started during the eighties (Bastiaanssen and Bos, 1999).

Remote Sensing has been able to provide information with varying degrees of success and accuracy on; irrigated area, crop type, biomass development, crop yield, crop water requirements, crop evapo-transpiration, performance diagnosis, salinity and water logging (Choudhury et al., 1994; Bastiaanssen and Makin, 2000). Available remotely sensed data remain underutilized by practicing water resource managers although Remote Sensing has several advantages which can be complementary to field measurements. Spatially distributed information on soil water availability of crops can contribute to enhance the statistics on water availability in space and time.

The spatial and Remote Sensing technique can be used to develop thematic maps of irrigation requirements to be used by decision-makers to define the maximum allowable irrigation withdrawals for a region (Heinemann et al., 2002). Ray and Dadhwal (2000) used Remote Sensing and Remote Sensing for estimating seasonal crop evapotranspiration. The methodology can be used for estimating weekly evapotranspiration and a real-time irrigation scheduling. The integration of RS data and Remote Sensing tools can be used to compute performance indices (Ray et al., 2002). The regular computation and monitoring of performance indicators could provide irrigation managers with the means for managing efficiently the irrigation system. Bastiaanssen and Bos, (1999) as described in his paper quantified irrigation performance indicators based on remotely sense data in cost effective manner. He suggested irrigation experts to use Remote Sensing techniques in evaluation of irrigation performance indicators for better irrigation management.

Benchmarking (BM), using a set of defined indicators to determine the performance of various components of irrigation system is very important to evaluate the irrigation performance and the applied management for the irrigation project. Suresh et al. (2012) used various components of irrigation systems namely Irrigation Infrastructure (IIS), Agricultural System (AS) and Water Delivery Dynamics (WDD) as performance evaluation indicators for benchmarking study of the Nagarajuna Sagar Left bank Canal (NSLC) using geospatial approach. Remote Sensing techniques can provide benchmark dataset of cropping, water distribution, baseline data and other data for comparing among the fields to evaluate the performance of irrigation or other management input. Geospatial approach for benchmarking of irrigation systems could be useful to evaluate the performance of irrigation through different performance indicators and compare the performance indicators within the command to identify the problem for better management (Suresh et al., 2012). The geospatial approach for Benchmark study in irrigation management enables the improvements in data collection methods over time consuming conventional field survey of large area providing alternative mechanism, diagnostic analysis, spatio-temporal visualization of BM indicators. Thus, the use of satellite data combining with field data on water deliveries could be an alternative to the conventional nonspatial approaches for BM Study useful for decision support for better management of irrigation projects and further better water resources planning and management. The benchmarking study can be very useful to diagnose how performance is varying along the space and facilitate quick diagnostic analysis of the problem for improved irrigation management.

1.5 Future Tool For Irrigation Water System

When dealing with spatial and temporal irrigation data, the tools without Remote Sensing support have major limitation that they cannot give output in the form of maps which are found to be very useful to visualize and understand by the farmers and irrigation experts. Tool, such as CROPWAT, ISAREG can provide wide range of facilities to carry out standard calculation for design and management of irrigation schemes, do not give input and output maps for use of the regional scale and basin scale. Remote Sensingsince many years, has been focused on analyzing remot,ely sensed data and only few tools have been developed in relation with irrigation management. With advances in sophisticated Remote Sensing tool and accurate methodology developed by irrigation requirements, experts are looking for new tool where visual maps, database and decision support system is available in single platform. Integration of remotely sense data is equally important to handle temporal irrigation data in irrigation management. In spite of development of few irrigation tools, both Remote Sensing based and no integration with Remote Sensing are not popular among farmers and irrigation experts because of complexity involved in many parameter and temporal data. The main limitation of these models is that they do not simulate in real time basis and are not user friendly. There is still need of work on development of irrigation management tool to fulfill the demand of irrigation experts and farmers which can give answer on spatial water requirements and water surplus/deficit of the command area.There is an easy way to develop to fulfill the gap of irrigation management tool inside ArcRemote Sensing using Integrated Development Environment. All spatial and non spatial irrigation data can be stored, analyzed and visualized using ArcRemote Sensing and these data can be customized using Integrated Development Environment to present all needed spatial water demand maps, irrigation map and water surplus/deficit maps. By using ArcRemote Sensing and the python language and ArcObjects for customization of Remote Sensing applications new tools for modeling of irrigation water requirements spatially and identifying corresponding water deficit/surplus can be designed. The tool may be used by irrigation authority and irrigation management consortia to analyze the water requirements and to take decision quickly and easier way. Automated weather stations, advance Remote Sensing technology, web technology to spread information, and sophisticated computer applications can further be combined to develop an effective tool for irrigation management. The next generation of irrigation management software will need to address the spatial and temporal data with automation. Further, the tool should be user friendly, efficient, automated and should address multitask associated with irrigation management. But the software to do that is inherently complex, and development of such software is beyond the resources of most individual states or agencies.

2. ABOUT THE STUDY AREA

Thanjavur is located at 10.8°N 79.15°E The tributaries of river Cauvery, namely, the Grand Anaicut canal (Pudhaaru), Vadavaaru and Vennaaru rivers flow through the city. Thanjavur is situated in the Cauvery delta, at a distance of 314 km (195 mi) south-west of Chennai and 56 km (35 mi) east of Tiruchirappalli. While the plains immediately adjoining the Cauvery river have been under cultivation from time immemorial, most of Thanjavur city and the surrounding areas lie in the "New Delta" - a dry, barren upland tract which has been brought under irrigation during the early 19th century. To the south of Thanjavur city, is the Vallam table land, a small plateau insterspersed at regular intervals by ridges of sandstone. The nearest seaport is Nagapattinam which is 84 km east of Thanjavur. The nearest airport is Tiruchirapalli International Airport, located at a distance of 56 km. The city has an elevation of 57 m above mean sea level. The total area of the city is 36.33 km^2

Thanjavur, formerly Tanjore is a city in the south Indian state of Tamil Nadu. Thanjavur is an important center of South Indian religion, art, and architecture. Most of the Great Living Chola Temples, which are UNESCO World Heritage Monuments, are located in and around Thanjavur. The foremost among these, the Brihadeeswara Temple, is located in the centre of the city. Thanjavur is also home to Tanjore painting, a painting style unique to the region.

Thanjavur is the headquarters of the Thanjavur District. The city is an important agricultural centre located in the Cauvery Deltaand is known as the "Rice bowl of Tamil Nadu". Thanjavur is administered by a municipal corporation covering an area of 36.33 km^2 and had a population of 222,943 in 2011. Roadways are the major means of transportation, while the city also has rail connectivity. The nearest airport is Tiruchirapalli International Airport, located 59.6 km away from the city. The nearest seaport is Karaikal Port, which is 94 km (58 mi) away from Thanjavur. Scholars believe the name Thanjavur is derived from Tanjan, a legendary demon in Hindu mythology. While the early history of Thanjavur remains unclear, the city first rose to prominence during the reign of Medieval Cholas when it served as the capital of the empire. After the fall of Cholas, the city was ruled by various dynasties like Pandyas, Vijayanagar Empire, Madurai Nayaks,Thanjavur Nayaks, Thanjavur Marathas and the British Empire. It has been a part of independent India since 1947. Figure.1 shows Tamilnadu district Map. Figure. 2 shows Study Area Map

2.1 Conceptual Design

In a sound watershed management framework, various complex decision making processes are involved with structural and non-structural practices that can be undertaken to optimize of land and water resources, prevent soil erosion, stabilize water demand, and to increase productivity through efficient land use planning. The WATMIS attempt illustrate the development of a viable and generic toolkit for integrated watershed planning and management of its natural resources. The system is conglomeration of multiple technologies like Geographical Information System (Remote Sensing), Remote Sensing (RS), Global Positioning System (GPS), hydrological modelling, soft-computing tools, etc.

Figure. 1 Tamilnadu district Map

Figure. 2 Study Area Map

2.2 Data Used

Various spatial, non-spatial, temporal, attribute, and thematic datasets were used in WATMIS. Satellite Data of Landsat 7 Enhanced Thematic Matter (ETM/ETM+), particularly in the growing phases of crops (September–December), were used for obtaining land use distributions as well as irrigation water necessitate. The meteorological (Julian day of year, mean relative humidity, solar radiation, open pan evaporation, wind speed, and daily minimum and maximum air temperature), cropping system, soil (field capacity, soil type, permanent wilting point) and watershed datasets were used for dynamic hydrological modeling to obtain max- imum crop yield through optimal allocation of watershed resources.

3. MATERIALS AND METHODS

3.1 Methodology Development

The use of REMOTE SENSING to design and plan irrigation systems requires a procedure for adequate analysis as is shown in the chart flow (Figure.3). The methodology developed and applied to this study consists of the following steps:

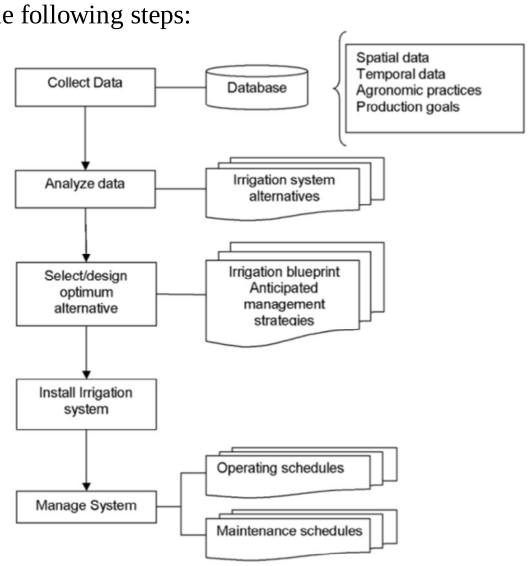

Figure 3. Methodology implemented in this work

Coordinates of each sampling point for the different information, as well as to develop the thematic layers for each parameter must be obtained.

3.2 Analysis

On the basis of the data, the spatial distribution for each parameter, considering the most restrictive areas and their weight in the total study area must be evaluated, for the design and management of the irrigation systems and the pipe distribution network. A thematic layer with the established irrigation system is incorporated.

The design system is done taking into account the procedure given by Holzapfel et al. (1984) for surface irrigation and for pressurized irrigation on the basis of Holzapfel et al. (1990) and Abarca (2002). For the optimal design of surface irrigation the length, time of cutoff and discharge must be considered (Holzapfel et al., 1985a; Walker & Skogerboe, 1987, Holzapfel et al., 2010). The optimal design of pressurized irrigation system takes into account, the selection of emitters (Holzapfel et al., 2007a, b), optimal design of subunits and optimal pipe diameter (Pizarro, 1996; Stuardo, 2006).

3.3 Data Collection

In this step the soil data as texture, water holding capacity, infiltration rate, bulk density; must be collected. In addition, topography, actual plots, constructions, irrigation network, drainage network georeferenced basic information, which requires the dynamic nature permits adaptation of irrigation system management to real-time conditions and even system design modification is permitted.

The use of this tool is also of great use in farm management and planning since it can also help in other activities necessary for the production process, such as crop rotation, changes in farm structures or their location, implementation of new crops with new irrigation systems.

3.4 General Farm Information

Thanjavur is located at 10.8°N 79.15°E The tributaries of river Cauvery, namely, the Grand Anaicut canal (Pudhaaru), Vadavaaru and Vennaaru rivers flow through the city. Thanjavur is situated in the Cauvery delta, at a distance of 314 km (195 mi) south-west of Chennai and 56 km (35 mi) east of Tiruchirappalli. While the plains immediately adjoining the Cauvery river have been under cultivation from time immemorial, most of Thanjavur city and the surrounding areas lie in the "New Delta" – a dry, barren upland tract which has been brought under irrigation during the early 19th century. The farm is located near the town which is 5 kms on the way to Kumbakonam.

3.5 Topographic Map

An existing topographic map (scale 1: 5000), with 0.5 m equidistance contour level curves is available. The map includes cultivated plots, internal roads, construction, drains and water sources. This map was digitalized, forming an independent thematic layer.

3.6 Farm Georeferencing

Using the previously described topographic map, characteristic points on the farm were selected for georeferencing using a GPS model GARMIN 12. These points were site vertexes, constructions, plot borders and other structures. Georeferencing was performed at several key points, at three different times and with three replications. This was done to minimize distortion errors and ensure good map adjustment in the northern sector, where the dominant slope goes from east to west with a mean value of 0.73%. In the southern sector, the slope value is 1.12% in the same direction.

3.7 Site-Specific Field Configuration

The spatial variability of agricultural fields has been widely addressed in precision agriculture however, optimizing field configurations for site-specific management in each field remains a difficult task. The spatial variation of the study site was examined in this paper so that a minimum number of in-field sensor systems could be placed with optimal impact for characterizing the scope of the field information. In this case, the optimal distribution of the in-field sensing stations was determined on the basis of the spatial soil variability. Soil properties such as a water-holding capacity can have a major impact on crop yield. Apparent soil electrical conductivity (ECa) was used to map the field for its variability, primarily as an indicator of water-holding capacity as well as salinity. ECa mapping has been widely used as one way to characterize variability of agricultural fields. The ECa is a measure of the amount of salt in soil, which is directly related to the water-holding capacity, and other soil properties such as the percentage of sand, clay, and organic matter.

3.8 In-Field Sensing Stations

The system components of the in-field sensing stations and weather station contained three main parts: data logging, wireless data communication, and power management. A data logger measured field sensors and was self-powered by a solar panel (SX5, Solarex, Sacramento, CA) that recharged a sealed lead acid 12-V battery (NP7-12, Yuasa Battery Inc., Laureldale, PA) through a voltage regulator (SunSaver-6, Morning star Corporation, Washington Crossing, PA). The sensory data were transmitted via a Bluetooth radio transmitter that is later described in detail.

- Data Logging
- Wireless Data Communication
- PowerManagement

3.8.1 Data Logging

Field data were logged by a data logger (CR10, Campbell Scientific Inc., Logan, UT) for five in-field sensing stations and one weather station. A peripheral interface was implemented with a nine-pin D-type connector that was converted to a serial communication through an optically isolated RS-232 interface adapter (SC32B, Campbell Scientific Inc.). All six data loggers used in this paper were programmed to read data at the same time and configured at 10 s for scanning and 15 min for the data storage and download. Two water content reflectometers (CS616, Campbell Scientific Inc.) were horizontally installed at 30- and 60-cm soil depth to measure the volumetric water content of soil. Soil temperature is a useful information to determine how temperature affects the soil water-holding capacity. A temperature probe (107, Campbell Scientific Inc.) measured soil temperature at the 30-cm depth and was also used for air-temperature measurement at the 60-cm height with a solar radiation shield. A humidity probe (HMP35C, Vaisala, Helsinki, Finland) was mounted with a solar radiation shield to measure relative humidity. A pyranometer (LI200X, Licor, Lincoln, NE) was horizontally leveled and provided measures of solar radiation as total flux and flux density.

3.8.2 Wireless Data Communication

Most wireless communications follow standard protocols such as the IEEE 802.11, Bluetooth, or Zigbee, which all use spread spectrum radio technology. Spectrum bands of 902–928 MHz, 2.4–2.48 GHz, and 5.7–5.85 GHz have been allocated for license-free spread spectrum devices [16]. The type of wireless standard in this paper was determined by the major factors of distance, data rate, compatibility, and cost. For the application in this paper, the field was located 700 m from the base station, and the data transfer rate required less than 1 kB per cycle in both transmitting and receiving due to a short text string of sensory data. Accommodating existing data loggers and sensors required plug-and-play compatibility to serial devices with cost-effective wireless communication modules. Based on allthe requirements for our application, a Bluetooth module was selected for the wireless data communication from the in-field sensing stations to a base station. Bluetooth is an international standard of short-range wireless communications. The key features of Bluetooth technology are robustness, low power, and low cost. The Bluetooth radio transmission uses a slotted protocol with a Frequency Hopping Spread Spectrum technique in the globally available unlicensed 2.4-GHz Industrial, Scientific, and Medical band. Each device is identified by a globally unique 48-bit address derived from the IEEE 802 standard. Bluetooth's 2.4-GHz hopping frequency system minimizes RF interference from sources such as a WLAN and maximizes user experience. Communication between Bluetooth devices follows a strict master–slave scheme, which is known as a piconet, in which the master defines the timing and the hopping patterns. A master device can simultaneously communicate with up to seven slave devices within a single piconet, and each device can also simultaneously belong to several piconets

3.8.3 Power management

The efficient use of power is critical for a long-term operational system. Wireless sensor nodes are mostly powered by batteries and require efficient power management for both data scanning from sensors and for wireless data communication. Communication protocol is more helpful in reducing power consumption than in hardware optimization. Power consumption was estimated based on two modes standby mode that draws power to maintain signal connection and active mode that draws more power to execute signal transmission. Based on a data logger that is running at a scanning interval of 10 s and Bluetooth radio transmission at a downloading interval of 15 min, daily total power consumption was 23.8 Wh. The total power supply from a battery and solar panel was 84 and 20 Wh, respectively. This indicates that the proposed power system will operate for 3.5 days if there is no sunlight. In fact, power dissipation was often observed due to rainy or cloudy days in our experiment during the first stage. When the Bluetooth device lost power slowly and the supply voltage dropped below 5 V, the communication link did not re-establish even after the battery was fully charged by solar radiation. This was caused by a manufacture's hardware design limitation. The power system was redesigned by modifying Bluetooth power management, since the majority of power consumption was used by the Bluetooth standby mode.

3.9 Irrigation Control Station

The wireless variable rate irrigation control and monitoring was implemented on 3.6-ha experimental plots that were laid out in 14 strips in the direction of travel. Each strip was planted with either sugar beet or malting barley, which alternated from year to year. There are a total of 56 plots with the individual plot being 15 m wide and 24 m long, including buffers. Each strip was divided into four plots with two plots being irrigated with midelevation spray application (MESA) and two with low energy precision application (LEPA) that are blocked by replication It had six towers including the "cart" on one end, on which an industrial diesel engine was mounted and coupled to a water supply pump and an electrical generator (480 V, threephase) to provide power for the tower motors and cart motors. A buried wire alignment system was used with the antennas located in the middle of the machine. The water supply for the linear-move machine was a screened floating pump intake in a level ditch. Nominal operating pressure was about 250 kPa. Two double direction boom backs were installed at each of the towers. Spans were 49 m in length except for the center span with the guidance system that was a 47-m span.

4. DETERMINATION OF PHYSICAL CHARACTERISTICS OF THE SOIL

For irrigation design and management purposes the following soil information is required: texture, bulk density and water holding capacity. To obtain these soil data, initially ten one meter soil test pits (profiles) were distributed following three transects, to assure good representation of the area. Given Remote Sensing's dynamic characteristic, a new soil characteristic sampled with additional test profiles were incorporated according to the field digital model data results for each of the parameters were analyzed. Simultaneously, these test profile were georeferenced in their spatial location in the map, including soil texture, water holding capacity and depth. In addition, close to the soil test profiles water infiltration rate were determined with double ring cylinder infiltrometer.

4.1 Texture

To digitalize a soil texture information a numeric code was used as shown in Table 1.

Table 1. Values of the different soil textures according to the international classification system

Texture	Code
Heavy Clay	11
Clay	10
Silty Clay	9
Clay Loam	8
Silty Clay Loam	7
Silty Loam	6
Sandy Clay	5
Loam	4
Sandy Clay Loam	3
Sandy Loam	2
Sand	1

Based on the proposed classification and the textural information from the test pits, thematic maps were constructed for each soil strata, which were differentiated by texture. Figure 3 presents the thematic layer for the first soil strata because this stratum is the most important for crop development.

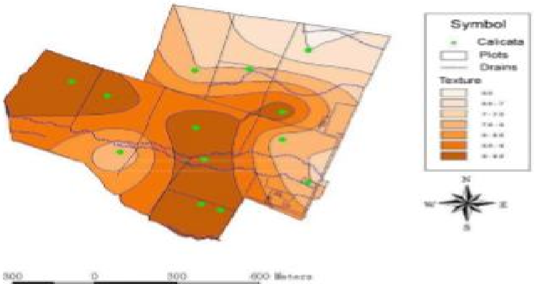

Figure 4 Thematic maps of farm

In general, from the texture thematic level, with a range between 7 and 10, it can be established that the soil is principally clayey (silty clay, clay loam and low density clay). This layer corresponds to the first soil profile strata analyzed. The origin of the studied soil is volcanic ash and it presents the characteristics of the Arrayán series (Molina, 1966). This type of soil generally presents high retention capacity and high infiltration velocity in the first few minutes.

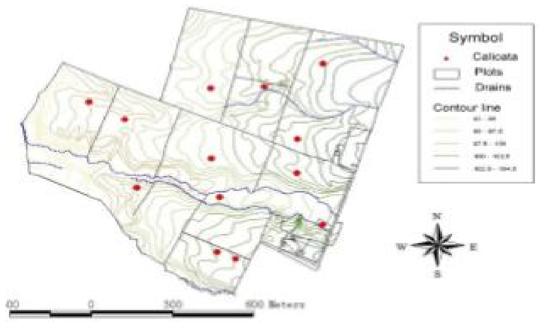

Figure 5 Thematic Maps Of Farm,Topography

4.2 Soil Water Retention

Soil water retention capacity is very important for irrigation system design and planning due to its relation with irrigation frequency and application times. The spatial distribution of this parameter is shown in Figure 4.It can be deduced that a large part of the farm has soil with high water retention up to 1 m depth with values that fluctuate between 12 cm m-1 occupying a surface of 16.4% of the farm, 33.7% present a value of 18 cm m-1, reaching 22 cm m-1 at certain points, although in only 0.2% of the farm area. These values are within the range cited by Molina (1966) for this type of soil. Additionally, it is important to establish that there is no great spatial variability in the water retention capacity of soil. Water retention capacity is affected not only by the soil texture but by other factors, such as organic matter content, structure, compaction, which act in complex ways. When the infiltration and the water retention thematic maps are analyzed, it can be established that the sectors with greater retention capacity are those with the lowest infiltration.

This result can be attributed to the smaller soil particle size in these sectors, retaining a greater quantity of water and impeding infiltration of water in the soil profile. When these thematic maps are compared with the texture thematic map, it can be observed that there is a certain concordance with the clayey sectors. Analysis of this thematic map provides the information to determine irrigation frequency for the design, tasking in to consideration factors such as the percentage of surface area under a determined water retention level. Additionally, different types of operation and management canbe identified for sectors that present characteristics different from those established for the design.

4.3 Infiltration Rate

Furthermore, the points used to determine the infiltration rate of water in soil, are the same as for the previously described profiles, and consequently other soil information could be related with this parameter. The infiltration rate curves obtained in each point indicate a similar tendency, decreasing abruptly in the first 30 min, characteristic that is generally presented in sandy soils and which is quite normal in this type of soils, derived from volcanic ash (Holzapfel et al., 1985b). In general, the infiltration rate was observed to stabilize at 120 min in most of the performed tests. However, it is important to consider that the soil infiltration rate did not greatly vary and that the values of 120 min are within the range of 0.03 and 0.08 cm min-1. In Figure 5 the soil infiltration rate thematic map corresponds to an infiltration time of 120 min. Other maps for different infiltration times can be incorporated if necessary, depending on the irrigation systems that can be feasibly implemented in the study area.

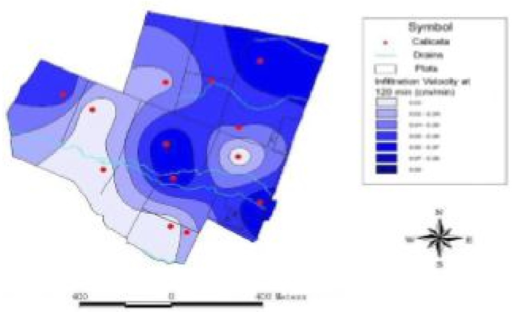

Figure 6 Thematic maps of infiltration rate

The infiltration rate of water in soil is a very important parameter for irrigation design and operation and is highly relevant in irrigation planning of a farm. Infiltration velocity has direct influence on the selection of pressurized irrigation emitters as well as on the operation of irrigation sectors since this should be performed in differentiated form depending on eache points infiltration value. In the case of surface irrigation, this will affect the design variables such as furrow length, irrigation time, and discharge. The results indicate that there is little variability in infiltration rate, which can be attributed to the lack of soil variability presented in the thematic mapof texture. The infiltration values to be considered should be in accordance with the irrigation methods to be implemented, associated to problems that could result, such as water buildup, surface runoff, or poor water storage for the crop or plant.

4.4 Irrigation Methods

The operation, design, and selection of irrigation methods require a variety of information, where the previously described Remote Sensing thematic maps provide a global vision of the design information. Another important factor is the crop type, which can continuously vary if these are annual crops. In the case study, sugar beet has been considered, however, blueberry orchard was selected as the fruit due to its future projection and establishment conditions in the area. The topography of the area presents certain limitations for the implementation of surface irrigation considering the soil characteristics. The slope in the middle sector of farm is 0.67 % in the east-west direction. However, from an irrigation planning perspective, this is an area with quite irregular topography since it has a very abrupt slope in the north-south direction, which creates certain limitations for surface irrigation.

5.CASE STUDY

Based on the information collected, basic feasible irrigation method selection criteria were established. Additionally, as the study advanced, decisions were continuously made, assuring a dynamic process.

5.1 Drip Irrigation For Small Fruit

Drip irrigation is a method that eliminates conduction losses and minimizes evaporation and percolation losses as well as controls the pattern with which water is distributed in the soil. Under adequate design, operation, and management conditions, it generates an environment with optimal physical, chemical and biological characteristics in the root area as required to achieve a production of greater quantity and quality. From an engineering and agronomic perspective, the fundamental objective of drip irrigation system design is to maintain water content in the soil, close to the field capacity in the root area for plants with high water extraction. The distribution and level of soil water should be such that the relation between the water-soil-plant factors optimizes water use and plant production performance.

5.2 Design Information

Since drip irrigation is a high frequency system, the existing water deficit and height differences between the water source and distribution points need to be defined to assure the correct pump capacity.As in the earlier cases, drip irrigation system design also requires analysis of the thematic maps of topography, infiltration rate, soil water storage capacity and soil texture, considered in the order of decreasing importance.

Infiltration rate, even though it is less relevant in drip irrigation than in sprinkler irrigation, is used to determine the emitter discharge to avoid water accumulation or surface runoff. Additionally, soil water storage capacity and soil texture can be used as management tools since water application can be more or less frequent depending on soil type of each sector. For example, if a sector has the high retention capacity and clayey soil, then more water should be applied at a lower frequency (every two days), producing better aeration in the rooting depth. The soil water storage capacity and the rate of infiltration in the design process will be 12 cm m^{-1}, and 0.03 cm min^{-1}, respectively. To locate the drip irrigation sub-units, site sectors with the best conditions for blueberry development were selected. Additionally, the dimension of the sub-units was defined considering a plantation plot of 3 x 1 m under daily irrigation conditions. For the studied plot, 20 sub-units of 2.8 ha were established according to the thematic map characteristics, selecting their optimal location. Simultaneously, two subunits were irrigated for a period of 1.6 hours, for a total irrigated surface area of 56 ha.

5.3 Farm Irrigation Planning

Farm irrigation planning considers the establishment of irrigation methods, water distribution, a control center, irrigated area, crop distribution, water demand and irrigation frequency. Planning can be influenced by diverse factors, such as: water availability, crop.

Table 2. Drip Irrigation Data For Design Of Irrigation Systems

Item	Unit	Magnitude
Irrigation Frequency	Day	1
Plant spacing	m	3 x 1
ETa	mm day^{-1}	6.05
Volume of waterplant^{-1} day^{-1}	L	19,1
No. of emittersplant^{-1}	Units	2
Emitter discharge	L hr^{-1}	4
Drip pressure	mca	12
Irrigation hours per set	hr	2.38
Irrigation hours available daily	hr	24
Water availability	L s-1	42
System capacity	L s-1	42
No. of plants per set	plants	18,900
Area simultaneously irrigated	m2	56,000
No. of set per day	units	10
Maximum irrigated area	ha	56
Pump	HP	30

Climate and physical characteristics of the soil. The objective of planning is to achieve greater efficacy in water management, which means in practice water savings without diminished crop performance (Holzapfel et al., 2009). Planning for the Crisoles Farm began with the identification of the feasible irrigation methods by studying the topographic conditions, water availability and crop requirements. Since water availability is restricted and the topography of farm is irregular, the use of the available water resources needs to be maximized by reducing the losses by surface runoff and consequently pressurized irrigation is required. Specifically, this study considers three possibilities: aspersion irrigation by a central pivot, sprinkler irrigation and drip irrigation.

In the case of sprinkler irrigation, the maximum irrigation frequency was considered important in planning. Irrigation frequency is related with the crop water requirement and the water retention capacity of the soil and in the case study was calculated at 10 days. For localized irrigation, a daily irrigation frequency was considered given soil characteristics and crop demand. Another important factor is flexibility in management of irrigation frequency and times, considering the specific site characteristics of each sector. When an irrigation sector has a higher infiltration velocity and good retention capacity, this sector can support a higher application velocity and less frequent irrigation.

The water reservoir and the distribution and water evacuation systems (pipes, canals, and drains) should be considered when planning. This information is easily managed in the map using a Remote Sensing because it can be used to locate structures and evaluate different operational scenarios. Furthermore, a Remote Sensing can rapidly identify structural dimensions. In the case study, the Remote Sensing identified the location of the control center between the two principal drains, a point where water from the two drains and from irrigation overflows can be captured. The pipe distribution system begins at this point.

6. CONCLUSION

A geographic information system (Remote Sensing) is a highly useful tool for farm irrigation design and planning. The information incorporated in the thematic maps establish a dynamic system useful for farm irrigation system management. Soil, crop, and topographic information can be spatially observed and analysed and basic design criteria, such as water application, irrigation frequency, and operation restrictions can be more easily established. Considering design and optimization criteria, with support of Remote Sensing, the feasible irrigation method for the Crisoles Farm was drip irrigation for small fruits. The location of the central control system and water distribution system was determined using the general vision of the farm provided by the Remote Sensing. A general criterion for irrigation system planning and design is to base decisions in tools that help make real-time decisions for site specific conditions. This study also provided extensive details for the wireless communication interface of sensors from in-field sensor stations and for a programmable logic controller from a control station to the computer at a base station.

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